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Applications

An integrated management support and production control system for hardwood forest products

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Spreadsheet and simulation models are tools which enable users to analyze a large number of variables affecting hardwood material utilization and profit in a systematic fashion. This paper describes two spreadsheet models, SEASaw and SEAIn, and a hardwood sawmill simulator. SEASaw is designed to estimate the amount of conversion from timber to lumber, while SEAIn is a log inventory module. The two spreadsheet modules are currently being interfaced and linked to an integrated system which will be optimized under the same spreadsheet environment. The simulator has the capability to describe in real time, the system performance of a hardwood sawmill under any specified operating conditions.

Keywords: Agriculture, Simulation, Sawmill, Forestry, Computer applications, Management support, Spreadsheet. Lotus 1–2–3.

1. Introduction

The efficient utilization of hardwood material has been a primary concern of forest product manufacturers for a number of years. However, efficient utilization should be viewed not only in terms of increased product yields but also in terms of economic efficiency— that is, increased revenues from the utilization of hardwood trees— from bucking to the primary processing of the logs to various intermediate or final products.

Several interrelated activities are involved in converting a tree into logs, and the logs into finished lumber. After the tree is felled, the limbs from the main trunk are removed, and subsequently the trunk or stem is cut into shorter logs. Bucked logs are then transported to the mill and allocated to one or more primary processing mills such as a sawmill or veneermill. The logs are subsequently sawn into lumber of sliced or peeled into veneer.

Under each step or activity, there exists a number of decisions and options upon which the potential yield or profit depends. These decisions present opportunities for increased economic return, or may also result in lost profits or reduction in the potential value obtainable from the tree.

Besides the physical activities or steps, other factors also affect the potential returns from the production and manufacturing processes. These factors include the quality or grade of the raw material and products, the market or demand schedule for the products, and the sources and availability of raw materials. All these factors should be considered, individually or collectively depending on the business interests of the forest product firm.

The hardwood forest product industry is very diverse, covering a wide variety of enterprises—

from timber buyers, logging contractors, sawmills, and other single-product firms, to the more progressive and integrated wood utilization complexes producing a variety of products, such as logs, lumber, veneer, and dimensions parts or cuttings. Each of these enterprises is in some way unique and adopts different management strategies.

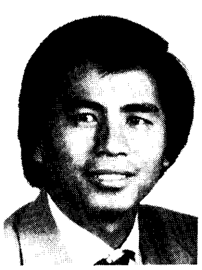
Regardless of the nature of the forest product firm, the managers are often faced with complex decision problems in attempting to achieve the maximum value from the raw materials, given constraints on the market, existing inventory stock, and supply of raw materials. For instance, log buckers are faced with the problem of determining the optimal bucking or cutting pattern for trees with different quality, dimension and species. The optimal mix of log grade combination produced will depend not only on the tree bucked but the intended end-use products (e.g., sawlogs, veneer logs, etc.). Likewise, the headrig sawyer should consider the result of the sawing process in deciding which mix of certain thicknesses of lumber should be produced given the current market prices and the recovery of various lumber grades.

Considering the complex decision problem and the multiple options facing the manager of a forest products firm, it is imperative that he have at his disposal some decision-aiding tools that allow him to evaluate his options. With the help of these tools, the manager is better able to make sound judgments, and consequently, better decisions.

The work described in this paper is a part of a larger project involving the development of a computer-assisted decision support system for the primary processing of hardwood forest products. To date, three computer programs have been partially developed. The first two are spreadsheet-based models and the last is a real-time simulator for hardwood sawmills.

2. Sawmill spreadsheet models

Microcomputer spreadsheets have proven to be versatile tools for managers in a variety of manufacturing enterprises. Spreadsheet-based models have been developed for a number of production



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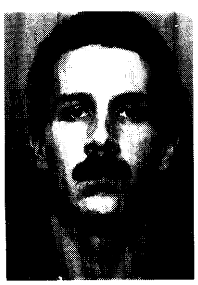

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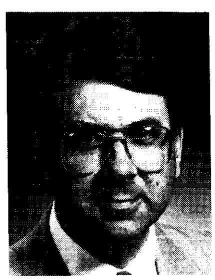

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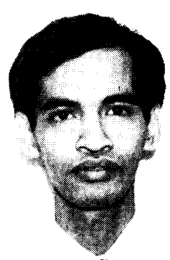

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and inventory management problems such as forecasting, inventory control, and production planning and scheduling. Personal-computer spreadsheet software are now routinely used in a number of ways and functions but primarily as a decision support to assist managers in their planning and decision making process.

The basic framework and operational characteristics of spreadsheets make them useful tools for sawmill production and operation planning.

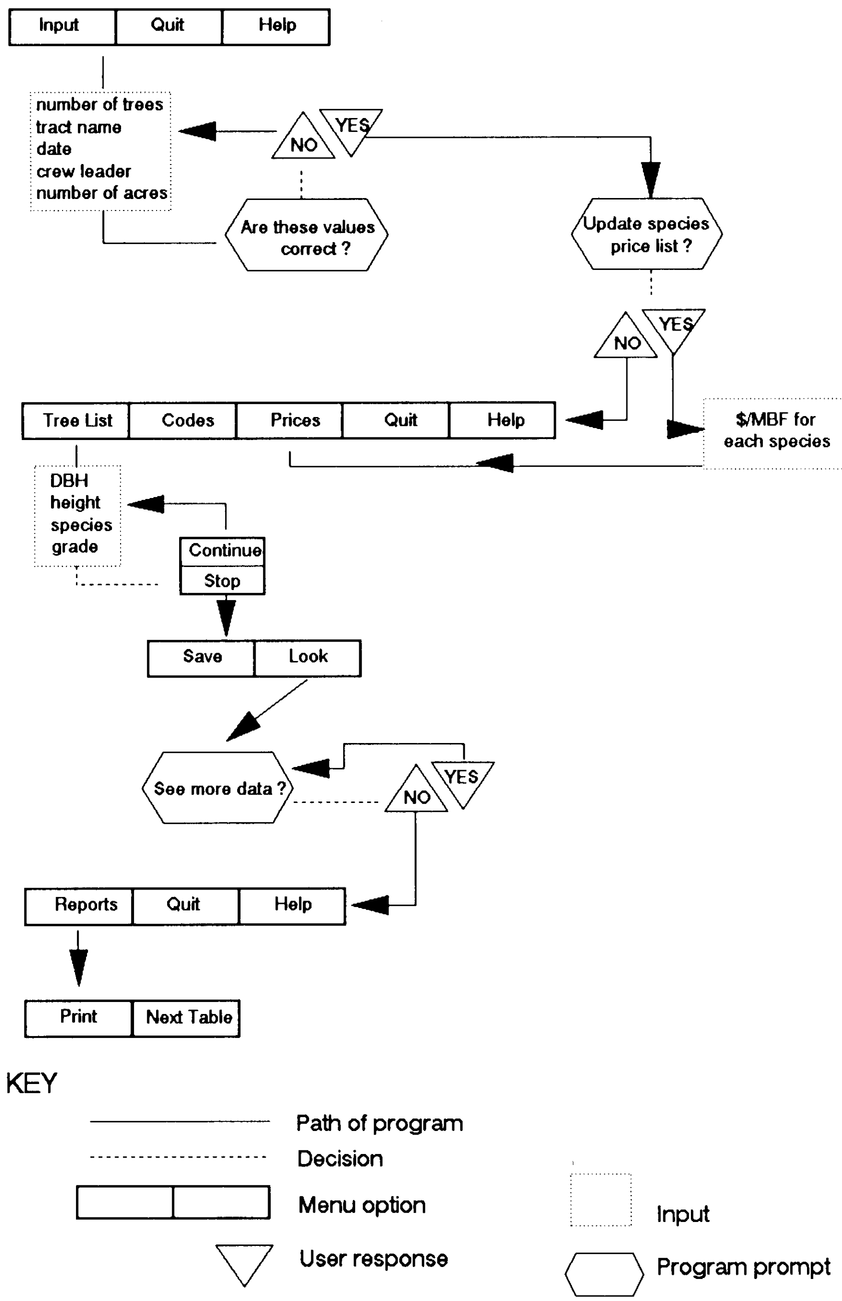

Fig. 1. Overall structure of SEASAW.

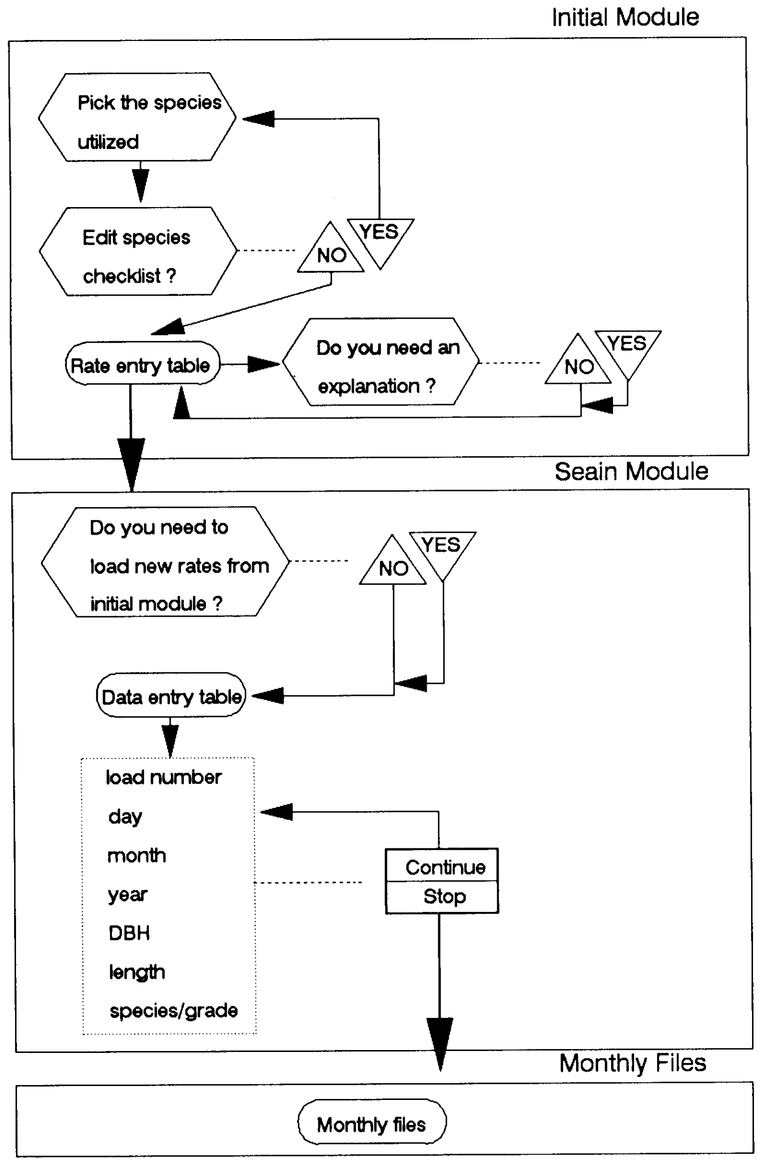

Fig. 2. Overall structure of SEAIN

Potential areas for their application include: product pricing, production planning including distribution, log procurement, and financial analysis, particularly bid analysis. Developing modules (or templates) for each of these problem areas under the spreadsheet environment is another convenient feature of spreadsheet models. These modules can also be linked or "interfaced" together to form a more comprehensive and integrated system. All these can be done using "built-in" capabilities of the spreadsheet.

Two spreadsheet based models have been developed for hardwood sawmill, namely: SEASaw (Spreadsheet Environment Analysis for Sawmills), and SEAIN (Spreadsheet Environment Analysis Inventory). Both SEASaw and SEAIN were developed using Lotus 123 [1] spreadsheet environment. They are designed to take advantage of Lotus's macro capabilities. A *macro* is a pseudo-program which performs any series of Lotus commands. To invoke a macro, the user presses a "hot-key", which in Lotus is the ALT key and one other predefine key from A to Z. In Lotus, a macro can also be defined to automatically start when the Lotus worksheet file is "opened".

2.1. SEASaw module

The actual equations used for estimating the conversion of lumber from standing trees are easily constructed in a Lotus spreadsheet environment. However, entering individual data, coefficients, and equations can be time-consuming, cumbersome, and even confusing. To alleviate this problem, SEASaw's macro conveniently provides a user-friendly and menu-driven spreadsheet for entering data, equations, and other information. Once the SEASaw file is loaded into Lotus, the macro will take over and begin "asking" the user for responses to questions which are typically Yes or No, or multiple options. Figure 1 shows the overall structure of SEASaw. The initial input required will setup the worksheet and allow the user to identify the current session by entering the tract name, date, and crew leader name. Next, the price per thousand board feet (MBF) for each species is entered.

The next menu will provide the option "Tree List" that will provide an entry form for entering the list of trees from each tract. This will require DBH (in inches), height (in feet), species code, and tree grade. A list of species codes can be printed before entering the "Tree List" option. Three tree grades are used based on the USDA conversion studies done by Hanks [2].

Once the data have been entered, SEASaw takes over and collects all of the correct coefficient values from within the file and performs all calculations needed. The next menu allows the user to get into the report section. This section gives a summary of the number of trees by species, and a table listing both the total volume and value by lumber grade and the total volume and value per acre by lumber grade. A similar table is produced for each species.

Conversion coefficients (i.e. rates) may be replaced by the user if a detailed conversion study has been undertaken following the study performed by Hanks [2]. Results from this production study can be fitted using the regression model below:

$$\mathrm{VOL} = a + b_1 \cdot \mathrm{DBH}^2 + b_2 \cdot \mathrm{HT} + b_3 \cdot (\mathrm{DBH}^2 \cdot \mathrm{HT}),$$

where a, b_1, b_2, b_3 are regression coefficients.

2.2. SEAIn module

SEAIn is similar to SEASaw in that it is also a user-friendly and menu-driven spreadsheet. Figure 2 gives the overall structure of SEAIn. SEAIn is designed to inventory the volume of logs in the mill by estimating the volume based on log diameter (DBH), length, and grade. Before running SEAIn a setup module is run to initialize the system by building a list of species used in the mill and the rates (i.e. prices) paid for a given log of a certain grade. Ten log grades are provided: veneer 1, veneer 2, prime 1, prime 2, grade 1 through grade 6. Once the rates have been entered the user presses the "hot key" (i.e. ALT-X) to automatically "open" SEAIn and begin the macro.

SEAIn will ask if new rates need to be entered from the initial module. If the rates already exist in SEAIn and no changes are needed, this step is skipped by the user. Next, the user enters the load number for reference, day, month, and year. Then a data entry form provides a convenient way of entering the data inputs on DBH, length, and species/grade code. This species/grade code consists of a 2-letter code for the species plus a 2-letter code for the grade.

Once all of the data have been entered, a monthly summary spreadsheet is "opened". Depending on the month entered in the beginning of the SEAIn module the inventory list is copied into the corresponding spreadsheet and a summary of total logs, total Doyle volume, and total cost for that month is displayed.

3. End user optimization with spreadsheet models

Optimization models of different kinds have traditionally been used in the forest products industry. Most of these models are designed following specific structures of formal mathematical programming models such as linear programming [3-5], dynamic programming [6–10], and simulation

[11-14]. Most of these models address specific processing problems such as log bucking and allocation. Integrated wood processing and allocation models have been developed by McPhalen [15], Mendoza and Bare [16] and Maness [17]. Industrial applications of some programming-based optimization models were reported by Hay ad Dahl [18], Hehnen et al. [19], and Lembersky and Chi [20].

Despite the apparent potential of these mathematical models to optimize wood processing activities, their application to real-world problems has been limited. This is partly because they are often regarded as too mathematical and incomprehensible to be successfully applied.

End-user optimization is becoming more widespread in a number of manufacturing enterprises. With the advent of better computer technology and increased numbers of user-friendly software, end-user optimization models have become more popular. One of the main instruments in bringing optimization to end-users is the spreadsheet model.

As pointed out earlier, the automatic recalculation capability of spreadsheet software enables the decision maker to quickly evaluate many different scenarios. This feature provides a quasi-optimization capability in which the decision maker can systematically evaluate a set of decision alternatives, modify one or more parameters, and evaluate their impacts. This interactive and iterative feature can be performed a number of times until an acceptable set of decision variables has been reached. While this simulation process allows the decision maker to make a "what-if" analysis, there is no guarantee that a "best" or even a "good" solution can be achieved. Fortunately, macro programs (e.g. templates) can be designed so that optimization can be achieved under the spreadsheet environment. Macros enable spreadsheets to become more than a descriptive model, with capability to do sensitivity analysis and optimization.

Today, several commercial spreadsheet optimization systems have been developed. For instance, optimization of spreadsheet models is described in [21-23]. Some of these commercial spreadsheet optimization systems currently available are VINO [21], What's Best [24] IFPS/Optimum [25], Optimal Solution Plus (Enfin Software Corp), and XA (Sunset Software Technology).

Existing spreadsheet optimization software differ in some respects. Some systems simply accept a problem formulation (e.g., linear programming (LP)) from a spreadsheet file, taking advantage of the spreadsheet features and capabilities in input entry. Other systems not only read the LP input from a spreadsheet file but also store the solution into another spreadsheet file. The most comprehensive integration and operational system is offered by the packages described above (e.g., XA, What's Best, VINO), where the user creates the spreadsheet input file and presses one or two keys to perform the optimization routine— that is, optimization is performed within the spreadsheet environment.

An overview of performing optimization within a spreadsheet program consists of identifying: (1) the cell which contains the objective; (2) the cells containing the decision variables to be adjusted during the optimization process; and (3) the cells which determine the feasibility of the values of decision variables.

Existing spreadsheet optimization models in forestry include Maness [17], which describes an application combining the optimization of log sawing and bucking strategies, and Leefers and Robinson [26], which describes a spreadsheet-

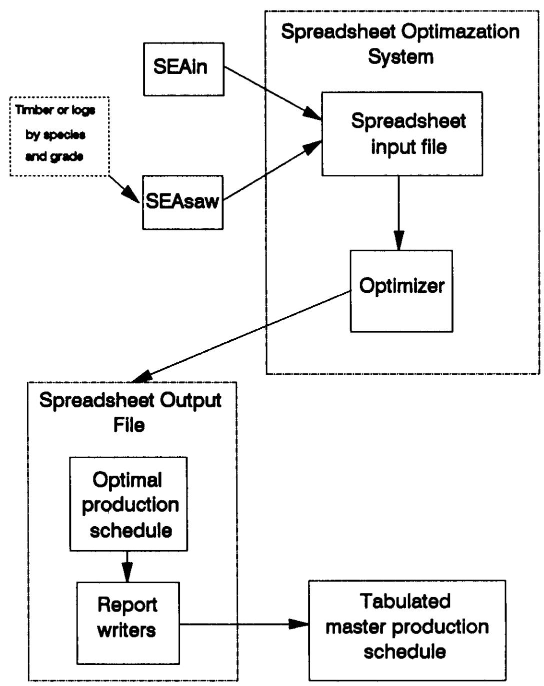

Fig. 3. Integrated Hardwood Optimization System.

based Forest Simulation–Optimization Model (FORSOM).

Efforts are now underway to integrate SEASaw and SEAIn into a comprehensive system that optimizes the log conversion process given different levels of timber or log input. This system will expand current capabilities of SEASaw beyond the estimation of the amount of conversion, both in terms of volume or in terms of economic (e.g., stumpage) values. The structure of the integrated Hardwood Optimization System is described in Fig. 3.

4. Real-time simulator for hardwood sawmills

As previously mentioned, simulation techniques have been used in investigating hardwood processing activities, with applications traditionally confined to two main areas: log yield maximization and design and evaluation of sawmill systems. However, despite their recognized potential, a number of barriers exist which have inhibited their industrial adaptation. Foremost among these obstacles are technological limitations of hardwares and softwares, lack of compatibility with existing operations, and lack of computer expertise.

Current simulation modeling efforts are becoming more comprehensive and integrated—constructing models to consider the inter-business issues within the manufacturing system instead of developing models for the singular use of one processing facility. The works of Adams [12] and Kline [27] are two examples of applying holistic simulation techniques to an integrated hardwood processing system. Such holistic models provide more realistic descriptions of real-life activities in a forest product manufacturing complex.

The real-time hardwood simulation model presented in this paper takes advantage of the modeling features of SIMAN [28]. SIMAN is among the popular, state-of-the-art simulation languages and has been practically used in many business applications. Its modeling orientation makes simulation much easier, and it has the ability to run in mini- and mainframe computers and personal computers. The language includes in one format the event scheduling mode, the process mode, and a statistical analysis system. In addition to these, the system allows simulated processes to be computer-animated (CINEMA).

Figure 4 shows the software organization of SIMAN and how various hardwood sawmill subprograms were linked to form a single system model. The SIMAN simulation framework offers a funda-

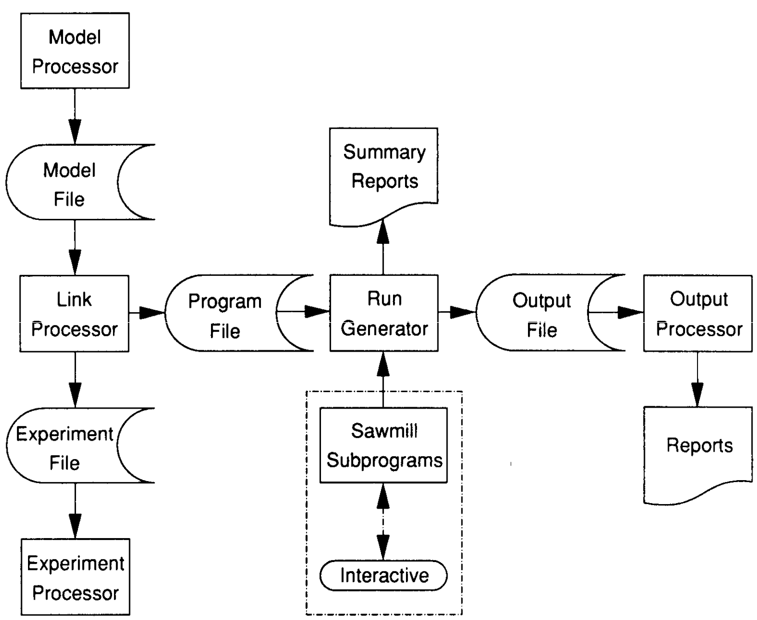

Fig. 4. Overview of the interface between SIMAN and the hardwood sawmill simulator.

mental distinction between the system model and the experimental frame. The system model defines the static and dynamic components of the system. The network feature of the sawmill — that is, the sequences of elements, operations, machines and queues, are portrayed in this mode. Currently, the sawmill's model file is divided into several stations: the log deck, the headsaw area, the edging and trimming areas and the lumber sorting area.

The experimental framework defines the experimental conditions under which the model is run. This section contains the length and diameter distributions, log and lumber grade distributions (by species), log arrival distributions, log and lumber grade distributions (by species), log arrival distribution, processing rates, conveyor speeds, distances between machines and so forth. SIMAN's link processor combines the model file and the experimental file to produce the program file. In doing simulation experiments with SIMAN, one has only to manipulate either the model or experimental file.

Before the simulation run is executed, the FORTRAN-coded subroutines containing the logic for breaking down the logs into flitches and the flitches into lumber are linked to the SIMAN's run processor. Currently, the subroutines include subprograms for generating information about the logs, decision routines on when to cut a slab or a flitch (either by livesawing or gradesawing), decisions on how to turn the log, and mathematical calculations for the edging and trimming operations.

After a simulation run, the user can analyze the results written in an output file. Without re-executing the simulation program, the user can subject one output file to many data treatments such as displaying histograms, plots, tables, data truncations, and ANOVA.

The hardwood simulation model is capable of producing several pieces of output information. Tables 1 and 2 contain some samples of the output generated by the simulator for a generic hardwood sawmill. Depending on which particular aspects of sawmilling an analyst wants to investigate, he can record observations and output statistics such as total number of logs processed (by species and grade), the piece-count, volume and grade of lumber produced, average sawing time of each log/lumber, time spent by a material in the system, in the queue or in a station, volume of sawmill by-products (slabs, edgings and sawdusts) and the utilization of machines and workers. Work is currently underway to include the production cost that could result from a particular sawmill operation.

Table 1
Output statistics from the hardwood simulator

Parameter (unit)	Average	Standard deviation	Minimum	Maximum
Headsawing time (min/log)	1.42	0.17	1.04	1.95
Log deck queue (pcs of logs)	29.44	1.82	0	30
Edger deck queue (pcs of lumber)	6.31	4.11	0	18
Headrig utilization	0.78	0.42	0	1.0
Edger utilization	0.99	0.06	0	1.0

Total time of simulation = 400.0 min.

Table 2
Sample input and output of materials simulated for a generic hardwood sawmill

Input materials	
Total log volume, ft 3	1814.78
Number of Aspen, logs	108
Number of Red Oak, logs	65
Number of Basswood, logs	98
Log Grade No. 1, logs	4
Log Grade No. 2, logs	41
Log Grade No. 3, logs	227
Output materials [a]	
Total pieces of lumber	2317
Total volume of lumber, BF	13165.81
FAS volume, BF	199.01
SELECTS volume, BF	256.88
COMMONS volume, BF	12710.03
Edging waste, BF	3067.98
Sawdust volume, BF	2754.89
Volume of shims, BF	767.63

[a] Other information such as work-in-process materials at end of operation can also be collected.

5. Summary and conclusions

Two spreadsheet models and a real-time hardwood simulator are described in this paper. These three modules are envisioned to comprise a computer-assisted decision support system for the primary processing of hardwood forest products. Functionally, SEASaw estimates the conversion of standing timber to lumber while SEAIn takes care of the inventory of logs that could go into the mill. conceptually, the output of the two modules could be fed into the proposed spreadsheet optimizing system to generate a master production plan. Before implementing the production plan, the user has the option of assessing first the performance scenarios of his production system under the derived production plan by utilizing the sawmill simulator. The information generated by the simulator could be used to adjust some of the mill's production policies to meet the production plan (or vice versa), or it can help provide adjustments in the conversion factors and product pricing that are used in the spreadsheet models.

Acknowledgement

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